Journal of Forestry Research (2009) 20(3): 243–248
DOI 10.1007/s11676-009-0035-x

RESEARCH PAPER

Coastal afforestation effects on soil properties at Hatiya in Bangladesh

K. M. Shaifullah, S. M. Sirajul Haque*, M. Sujauddin, Shyamal Karmakar

Institute of Forestry and Environmental Sciences, *University of Chittagong*, *Chittagong 4331*, *Bangladesh*

Abstract: An exploratory study was conducted in the coastal plantation (12- and 17-year-old *Sonneratia apetala*) of Char Alim and Char Piya and on their adjacent barren lands at Char Rehania and Char Nurul Islam in Hatiya of Noakhali district, in Bangladesh to determine afforestation effects on soil properties. At soil depths of 0–10, 10–30 and 30–40 cm across three different land strips viz. inland, middle and sea side in 12- and 17-year-old keora (*Sonneratia apetala*) plantations, soil moisture, particle density, organic matter and C, total N, pH, available P, K, Na, Ca and Mg were significantly ($p \leq 0.05$, $p \leq 0.01$, $p \leq 0.001$) higher, and soil salinity significantly ($p \leq 0.001$) lower than that in their adjacent barren lands. Soil moisture, particle density, organic matter and C, total N, pH, soil salinity, available P, K, Na, Ca and Mg of surface soil in Char Alim plantation at inland were 31.09%, 2.24 g·cm^{-3}, 2.41%, 4.14%, 0.58%, 7.07, 0.09 dS·cm^{-1}, 28.06 mg·L^{-1}, 0.50 mg·L^{-1} 11.5 mg·L^{-1}, 3.30 mg·L^{-1} and 2.7 mmol·kg^{-1}, respectively. Their corresponding values for the same depth and land position at adjacent Char Rehania barren land were 16.69%, 1.25g·cm^{-3}, 0.43%, 0.74%, 0.25%, 6.57, 0.13 dS·cm^{-1}, 13.07mg·L^{-1}, 0.30 mg·L^{-1}, 1.4 mg·L^{-1}, 0.30 mmol·kg^{-1} and 0.50 mg·L^{-1}, respectively. Soil moisture, particle density, organic matter and C, total N, pH, available P, K and Ca decreased, and soil salinity, available Na and Mg increased from inland towards sea side in the plantations. Although soil texture did not differ in most soil depths between plantation and adjacent barren land, proportion of sand particle was significantly ($p \leq 0.01$) lower and silt particle significantly ($p \leq 0.001$) in the plantations higher than that in their adjacent barren lands. In the study, evaluation of all the parameters was also done for the other pair of lands.

Keywords: coastal afforestation; keora plantation; soil physicochemical properties; afforestation effect; soil texture; soil base cations; *Sonneratia apetala*; Bangladesh

Introduction

Coastal region of Bangladesh is characterized by large number of river network with huge amount of water in rainy season between July and September. Another aspect related to the hydrology of the country is the process of sedimentation. Three main rivers – the Ganges, Brahmaputra and Meghna of Bangladesh, originated in Himalayas and passing through upland countries such as India, Nepal and China, carry a tremendous amount of sediment to Bangladesh. Coastal zone is about 710 km long extending along the Bay of Bengal, comprising estuaries and offshore islands and covers 19 districts including Bagerhat, Barguna, Barisal, Bhola, Chandpur, Chittagong, Cox's Bazar, Feni, Gopalganj, Jessore, Jhalokati, Khulna, Lakshmipur, Narail, Noakhali, Patuakhali, Pirojpur, Satkhira and Shariatpur, out of 64 districts in the country. Natural disaster like cyclone, storm surge and flood in this areas cause massive damage of lives and properties. Plantation of coastal areas with mangrove species in Bangladesh was initiated in 1960 to mitigate disastrous effects of cyclones and storm surges, to produce timber for fuel wood and industrial use and to conserve and stabilize newly accreted lands, which ultimately transferred a large part of such lands to agriculture (Siddiqi 2001). Sundarban, the unique natural mangrove ecosystem in the world, exists in this region. Major mangrove species planted on the newly accreted lands along the coastal belt, estuaries and river banks were *Sonneratia apetala*, *Avicennia officinalis*, *A. marina*, *A. alba*, *Amoora cucullata*, *Bruguiera gymnorrhiza*, *Excoecaria agallocha*, *Xylocarpus mekongensis*, *Ceriops decandra* and *Nypa fruticans* (Das et al. 1985). Up to 2002–2003, a total of 148 7 92 ha of mangrove plantations have been established through different development projects (Shamsuddin et al. 2003).

Combination of natural and man-made hazards such as river-bank erosion, high concentration of arsenic in ground water, earthquake, water logging in places with salinity and climate change have adversely affected lives and livelihoods in the coastal zone and slowed down the pace of social and economic development. Mangrove reduces cyclones, enhances land maturation, stabilizes shoreline, prevents river-bank erosion, reduces soil salinity, enhances activities of heterotrophic micro organ-

Received: 2008-12-29; Accepted: 2009-01-13

The online version is available at http://www.springerlink.com
Biography: K. M. Shaifullah (1982), Male, Institute of Forestry and Environmental Sciences, University of Chittagong, Chittagong 4331, Bangladesh. (E-mail: kazi_shaifullah@yahoo.com)
*Corresponding author: S. M. Sirajul Haque, Email: sms_haque@yahoo.com; Tel.: +88-01712239814; +88-031-2580435
Responsible editor: Zhu Hong

isms through uplifting nutritive value of the soil, provides necessary nutrient and habitat for fish and wildlife species, and offers significant ecological services in coastal ecosystems (Rao et al. 2007). Physicochemical conditions such as salinity, oxidation status and nutrient availability directly and indirectly influence mangrove growth and reproduction, and in turn mangroves influence soil physicochemical characteristics (Hossain 2002). Coastal afforestation affects soil properties like soil texture, color, water retention capacity, pH, salinity, organic matter and total nitrogen availability (Bandyopadhyay 1995; Khan et al. 1998; Jonston et al. 1995; Pal et al. 1996; Hasan 2000; Cardona et al. 1998; Sukardjo 1978; Eswaran et al. 1993; Machiwa et al. 1998). Afforestation activities along Noakhali coast of Bangladesh with mangrove species were started from 1967. *Sonneratia apetala* was a pioneer species for afforestation of newly accreted land, while partially stabilized and slightly raised lands afforested with *Excoecaria agallocha* and *Avicennia officinalis*. Up to 2003−2004, about 57 433 ha of coastal lands were afforested (ICZMP 2007). Many researches were done on the effects of coastal afforestation on soil properties in global perspectives (Botao et al. 1984; Gunasekaran et al. 1992; Cardona et al. 1998; Tam et al. 1998; Matthijs et al. 1999), but in Bangladesh, only a few works done in coastal areas (Haque et al. 2000; Siddiqi 2001; Shaifullah et al. 2008). Owing to this background, the present study was an attempt to assess the effects of coastal afforestation on soil physicochemical properties in Hatiya coast in Noakhali district.

Materials and methods

Collection of soil samples

The study was conducted from October 2006 to January 2008 at two pair lands at Hatiya Island under Noakhali Coastal Forest Division in Bangladesh. First pair land was 12-year-old keora (*Sonneratia apetala*) plantation at Char Alim with adjacent Char Rehania barren land under Sagaria Forest Range. Second pair land was 17-year-old keora plantation at Char Piya with adjacent Char Nurul Islam barren land under Nalchira Forest Range. Char Alim plantation covered 858 ha and Char Piya 819 ha. Based on inundation depth, each of the plantations as well as barren lands was divided into three land strips: inland, middle part and sea side, each of 100 m width. In each land strip, two sample plots of 50m×50m in size were demarcated at 30 m apart. Soils were collected at three successive depths: 0−10 cm, 10−30 cm and 30−40 cm. The first depth was confined to top soil on the idea that maximum tree effect might be within 0−10 cm depth with the addition of litter as well as due to maximum root activities of planted trees and associated natural coming plant species. Effect of vegetation gradually may reduce to increased soil depth for which the second depth was wider, i.e. 10−30 cm and the third depth contained remaining portion of 40 cm core sampler. For each soil depth and each plot, 14 samples were collected randomly using core auger and mixed together to give a composite sample. Thus, 36 composite soil samples were taken from three soil depths in plantations and 36 from barren lands for analyzing the physicochemical properties in the laboratory.

Soil analysis

In the laboratory the collected moist soil samples were separated in two portions. One portion was air dried, sieved through 10-mm mesh in size to remove gravel, small stones and coarse roots. This portion was used to determine soil texture by hydrometer method, moisture content, pH (1:2 soil water ratio), soil salinity, available P (Bray and Kurtz method), available Na, K, Ca and Mg according to Huq et al. (2005) and Petersen (2002). The other portion was oven dried to determine soil organic C and organic matter by loss of ignition method (Ball 1964), particle density and total nitrogen (micro-Kjheldhal digestion method). All the data were analyzed statistically using Statistical Package SPSS.

Results and discussion

Soil texture

Although soil texture did not differ in most of the pair sites, proportion of sand particle was significantly ($p \leq 0.01$) lower and silt particle significantly ($p \leq 0.001$) higher in both the planted sites than their adjacent barren sites (Table 1). Three soil textures viz. sandy loam, loamy sand and loam were found in both the plantation sites, whereas only sandy loam texture existed in the adjacent barren char land. Sand, silt and clay contents in surface soil (0−10 cm) at Char Alim coastal plantation were 56.58%, 36.72% and 6.50% at inland; 62.08%, 33.92% and 4.00% at middle part; and 68.48%, 21.18% and 10.40% at sea side, respectively, while their corresponding values at Char Rehania barren land were 76.48%, 16.32% and 7.20% at inland; 63.28%, 24.72% and 12.00% at middle part; and 83.28%, 15.52% and 4.20% at sea side. Similar textural differences were found from soil depths of 10−30 cm and 30−40 cm between the pairs of lands. At all the three depths and land positions between other pair of sites, i.e., Char Piya plantation and Char Nurul Islam barren land showed similar differences for soil particles (Table 1). This finding indicated that coastal plantation through trapping increased silt contents on one side, and more sand particles were deposited on barren lands in absence of vegetation due to larger size and more weight of the particles on the other side. This finding was in agreement with Kabir (2005), Sukardjo (1978) and Shaifullah et al. (2008). Similar differences for soil particles under keora (*Sonneratia apetala*) plantation, compared to the adjacent barren land, were found by Kabir (2005) in Chittagong and by Shaifullah et al. (2008) in Lakshmipur district of Bangladesh. Sukardjo (2007) found that the mangroves had a significant role in increasing clay and silt parentage and reducing sand percentage of coastal soils in mangrove forest of Java, Indonesia.

Soil physicochemical properties

At soil depths of 0−10, 10−30 and 30−40 cm on inland, middle

and sea side both in Char Alim and Char Piya plantations, the soil moisture, particle density, pH, organic matter and C, total N, available P, K, Na, Ca and Mg were significantly (p≤0.05, p≤0.01, p≤0.001) higher and soil salinity significantly (p≤0.001) lower in their adjacent Char Rehania and Char Nurul Islam barren lands, respectively (Tables 2–4). Soil moisture, particle density, pH, organic matter and C, total N, available P, K and Ca decreased and soil salinity, available Na and Mg increased from inland towards sea side in both the plantations.

Table 1. Soil texture in coastal plantation and adjacent barren char across three land strips at Hatiya, Bangladesh

Land position	Soil depth (cm)	Char. Alim plantation				Char. Rehania barren land				Char. Piya plantation				Char. Nurul Islam barren land			
		Sand (%)	Silt (%)	Clay (%)	Texture	Sand (%)	Silt (%)	Clay (%)	Texture	Sand (%)	Silt (%)	Clay (%)	Texture	Sand (%)	Silt (%)	Clay (%)	Texture
Inland	0-10	[a] 56.88 **	36.72***	6.50	SL	76.48**	16.32***	7.20	SL	56.48**	40.72***	2.80	SL	63.28**	28.72***	8.00	SL
	10-30	58.08**	37.92***	4.00	SL	70.08**	18.92***	10.00	SL	50.08**	44.72***	5.20	SL	60.48**	31.52***	8.00	SL
	30-40	51.28**	40.72***	8.00	SL	67.28**	20.92***	11.80	SL	46.28**	36.72***	16.0	L	56.48**	31.52***	12.00	SL
Middle	0-10	62.08**	33.92***	4.00	SL	63.28**	24.72***	12.00	SL	50.08**	41.92***	8.00	SL	67.08**	27.52***	5.20	SL
part	10-30	63.28**	35.92***	0.80	SL	62.88**	27.92***	9.20	SL	62.08**	35.52***	2.40	SL	70.08**	25.92***	4.60	SL
	30-40	52.88**	37.92***	9.20	SL	63.28**	24.72***	12.00	SL	58.08**	37.92***	4.00	SL	58.08**	33.92***	8.00	SL
Sea side	0-10	68.48**	21.18***	10.40	LS	83.28**	15.52***	1.20	SL	60.48**	35.52***	4.00	SL	75.28**	19.52***	5.20	SL
	10-30	55.28**	36.7***	8.00	LS	80.88**	15.12***	4.00	SL	52.48**	45.00***	2.52	L	71.28**	24.72***	4.00	SL
	30-40	68.48**	21.08***	10.40	SL	74.08**	16.72***	9.20	SL	48.08**	44.72***	7.20	L	66.08**	25.92***	8.00	SL

Notes: [a] indicates mean of seven composite soil samples in the field at each land use type; ** and *** indicate significance difference at p≤0.01 and p≤0.001 for the means between two land uses at each soil depth; SL= Sandy loam, L= Loam, LS= Loamy sand.

Table 2. Soil physicochemical properties in coastal plantation and adjacent barren char across three land strips at Hatiya, Bangladesh

Land position	Soil depth (cm)	Char. Alim plantation				Char. Rehania barren land			
		Moisture content (%)	Particle density (g·cm^{-3})	pH	Salinity (dS·cm^{-1})	Moisture content (%)	Particle density (g·cm^{-3})	pH	Salinity (dS·cm^{-1})
Inland	0-10	31.09***	2.24***	7.07***	0.09***	16.69***	1.25***	6.57***	0.13***
	10-30	29.16***	2.21**	7.17***	0.08***	22.02***	1.37**	6.47***	0.14***
	30-40	25.71***	2.33***	7.53***	0.12***	20.30***	1.40***	6.20***	0.12***
Middle	0-10	26.21***	2.00	7.13	0.12**	21.15***	1.22	5.83	0.13**
	10-30	26.04***	2.18***	6.97***	0.11*	22.78***	1.47***	6.17***	0.13*
	30-40	23.80***	2.21***	7.17***	0.11***	20.05***	1.68***	6.33***	0.13***
Sea side	0-10	23.00***	1.99***	6.87***	0.13***	23.33***	1.47***	5.70***	0.14***
	10-30	29.58***	2.07**	7.00***	0.12***	22.60***	1.37**	5.97***	0.15***
	30-40	26.00***	1.94***	7.00***	0.11**	21.95***	1.30***	6.17***	0.14**
Land position	Soil depth (cm)	Char Piya plantation				Char Nurul Islam barren land			
		Moisture content (%)	Particle density (g·cm^{-3})	pH	Salinity (dS·cm^{-1})	Moisture content (%)	Particle density (g·cm^{-3})	pH	Salinity (dS·cm^{-1})
Inland	0-10	46.03***	2.15***	7.60***	0.11***	26.59***	1.67***	6.70***	0.12***
	10-30	47.11***	2.33**	7.30***	0.11***	27.62***	1.74**	6.97***	0.09***
	30-40	41.63***	2.40***	7.03***	0.09***	21.95***	1.83***	7.07***	0.09***
Middle	0-10	41.29***	2.31	7.17	0.10**	25.46***	1.81	7.06	0.13**
	10-30	36.52***	2.24***	7.40***	0.11*	24.46***	1.87***	6.67***	0.12*
	30-40	37.90***	2.07***	7.13***	0.10***	27.56***	2.15***	6.93***	0.13***
Sea side	0-10	38.36***	1.94***	7.07***	0.12***	29.67***	1.63***	6.33***	0.14***
	10-30	36.61***	2.01**	7.10***	0.12***	28.36***	1.72**	6.70***	0.14***
	30-40	34.76***	2.00***	7.03***	0.10**	25.56***	1.88***	6.83***	0.14**

Notes: *, ** and *** indicate significance difference at p≤0.05, p≤0.01 and p≤0.001, respectively, for the means between two land uses at each soil depth.

In Char Alim coastal plantation, the moisture contents at all the three land positions in the surface were 31.09%, 26.21% and 23.00%, respectively, and their corresponding values on the Char Rehania barren land were 16.69%, 21.15% and 23.33%. Similar differences were between Char Piya plantation and Char Nurul Islam barren land (Table 2). Similar differences for soil moisture

were observed by Jonston and Alongi (1995) in the coastal forest of Mekong delta of Vietnam, Hossain (2002) in estuarine mangrove plantations at Cox's Bazar district and Shaifullah et al. (2008) in keora plantation at Lakshmipur district in Bangladesh. Differences in moisture contents between the plantations and adjacent barren lands at Hatiya were more than those in inland either middle or seaside position.

Soil particle densities of the surface soil in Char Alim plantation at inland, middle part and sea side were 2.24, 2.00 and 1.99 $g \cdot cm^{-3}$, respectively, and their corresponding values on barren land 1.25, 1.22 and 1.47 $g \cdot cm^{-3}$. In Char Piya plantation for the same soil depth and land positions, particle densities were 2.15, 2.31 and 1.94 $g \cdot cm^{-3}$, respectively, and their corresponding values on Char Nurul Islam barren land 1.67, 1.81 and 1.63 $g \cdot cm^{-3}$ (Table 2). Watt et al. (2005) and Kabir (2005) also reported similar findings for soil particle. Watt et al. (2005) found that soil particle density in forested coastal land was higher than either degraded or barren land. Particle density increased with soil depth in both the pair sites at Hatiya (Table 2). Kabir (2005) also found that soil particle density increased with soil depth in keora plantation in Chittagong.

Soil pH in the surface of Char Alim keora plantation at inland, middle part and sea side was 7.07, 7.13 and 6.87, respectively, with their corresponding values in the adjacent barren land of 6.57, 5.83 and 5.70. For the same soil depth and land positions, pH in Char Piya plantation was 7.60, 7.17 and 7.07, and in adjacent barren land 6.70, 7.06 and 6.33, respectively (Table 2). Many reports (e.g., Gill et al. 1990; Lacerda et al. 1995; Tam et al. 1998; Hossain 2002) on coastal region from home and abroad were in support of this finding. Gill and Abrol (1990) recorded higher pH in the coastal sandy soil, compared to the adjacent agricultural land in Andhra Pradesh, India. Tam and Wong (1998) also found higher pH under coastal soil in a subtropical mangrove ecosystem in Honkong.

Soil salinities in the surface soil of Char Alim keora plantation at inland, middle part and sea side were 0.09, 0.12 and 0.13 $dS \cdot cm^{-1}$ with their corresponding values in the barren lands 0.13, 0.13 and 0.14 $dS \cdot cm^{-1}$, respectively. For the same depth and land position, soil salinities in Char Piya keora plantation were 0.13, 0.14 and 0.14 $dS \cdot cm^{-1}$ and adjacent Char Nurul Islam barren land contained 0.12, 0.13 and 0.14 $dS \cdot cm^{-1}$ (Table 2). Lowering of salinity through keora plantation was also reported by Kabir (2005) in Chittagong. Cardona and Boetro (1998) found that soil salinity in the Caribbean increased from land toward sea side.

Table 3. Soil chemical properties in coastal plantation and adjacent barren char across three land strips at Hatiya, Bangladesh

Land position	Soil depth (cm)	Char. Alim plantation				Char. Rehania barren land			
		Organic C (%)	Organic M (%)	Total N (%)	Avail. P ($mg \cdot L^{-1}$)	Organic C (%)	Organic M (%)	Total N (%)	Avail. P ($mg \cdot L^{-1}$)
Inland	0-10	2.41***	4.14***	0.58***	28.06***	0.43***	0.74***	0.25***	13.07***
	10-30	2.38***	4.10***	0.27	16.11***	0.12***	0.20***	0.09	27.30***
	30-40	2.36***	4.06***	0.26***	12.55**	0.52***	0.90***	0.30***	15.43**
Middle	0-10	1.88***	3.23***	0.58***	17.25***	0.38***	0.65***	0.25***	9.65***
	10-30	2.44***	3.20***	0.17***	17.58***	0.27***	0.46***	0.20***	8.19***
	30-40	2.00***	3.44***	0.21***	17.25**	0.50***	0.86***	0.18***	9.05
Sea side	0-10	1.51***	3.26***	0.17***	20.31***	0.26***	0.45***	0.13***	5.95***
	10-30	1.41***	3.15***	0.12***	14.75***	0.41***	0.70***	0.32***	11.20***
	30-40	1.10***	3.21***	0.14**	7.42	0.44***	0.76***	0.12**	3.04**
Land position	Soil depth (cm)	Char Piya plantation				Char Nurul Islam barren land			
		Organic C (%)	Organic M (%)	Total N (%)	Avail. P ($mg \cdot L^{-1}$)	Organic C (%)	Organic M (%)	Total N (%)	Avail. P ($mg \cdot L^{-1}$)
Inland	0-10	2.25***	3.87***	0.27***	23.00***	1.52***	2.62***	0.12***	20.92***
	10-30	2.22***	3.82***	0.20	26.30***	1.84***	3.16***	0.18	18.37***
	30-40	1.85***	3.90***	0.25**	15.98**	1.92***	3.31***	0.17***	15.89**
Middle	0-10	2.09***	3.60***	0.18***	22.76***	1.26***	2.18***	0.12***	10.32***
	10-30	2.10***	3.62***	0.17***	20.28***	1.28***	2.81***	0.05***	20.83***
	30-40	1.85***	3.18***	0.14***	14.48	0.85***	1.79***	0.02***	15.66
Sea side	0-10	2.20***	3.59***	0.18***	14.60***	1.16***	1.96***	0.02***	21.11***
	10-30	1.70***	2.93***	0.10***	19.63***	0.81***	1.39***	0.05***	28.38***
	30-40	1.46***	2.52***	0.13**	14.64**	0.66***	1.97***	0.13**	19.50**

Notes: ** and *** indicate significance difference at $p \leq 0.01$ and $p \leq 0.001$, respectively, for the means between two land uses at each soil depth.

Organic C contents in surface soil at inland, middle part and sea side of Char Alim plantation were 2.41%, 1.88% and 2.51%, respectively, while their corresponding values in Char Rehania barren land 0.43%, 0.38% and 0.26%. For the same depth and land positions in Char Piya coastal plantation soil organic C contents were 2.25%, 2.09% and 2.20%, respectively, with their corresponding values 1.52%, 1.26% and 1.16% in Char Nurul Islam barren land (Table 3). More organic C was found in keora plantations, compared to their adjacent barren lands in the present study. Mangrove litter is one of the important sources of

organic carbon in soil through accumulation of mangrove stem, leaf litter and dead roots at varying depth (Lacerda et al. 1995; Tam et al. 1998; Machiwa et al. 1998; Shaifullah et al. 2008).

Total N contents in the surface soil of Char Piya plantation at three land positions were 0.27%, 0.18% and 0.18%, respectively, while their corresponding values in Char Nurul Islam barren land were 0.12%, 0.12% and 0.02%. For the same depth and land positions, total N contents in Char Alim plantation were 0.58%, 0.58% and 0.17%, respectively, with their corresponding values 0.25%, 0.25% and 0.13% in Char Rehania barren land (Table 3). Similar differences between two land uses were reported by Shaifullah et al. (2008) and Hossain (2002) in other parts of the coastal region in Bangladesh.

Available P contents in the surface soil of Char Alim plantation in inland, middle part and sea side were 28.06, 17.25 and 20.31 mg·L^{-1}, respectively, and their corresponding values in the three land positions on Char Rehania barren land contained 13.07, 9.65 and 5.95 mg·L^{-1}. For the same depth and land positions in Char Piya coastal plantation, available P contents were 23.00, 22.76 and 14.60 mg·L^{-1}, with their corresponding values 20.92, 10.32 and 21.11 mg·L^{-1} in Char Nurul Islam barren land (Table 3). Singh et al. (1985) found higher P contents in the surface soil under coastal forest of Andaman in comparison to Nicobar Islands in India, which supported the present findings.

Table 4. Soil base cations (mmol·kg^{-1}) in coastal plantation and adjacent barren char across three land strips at Hatiya, Bangladesh

Land position	Soil depth (cm)	Soil base cations (mmol·kg^{-1})							
		Char. Alim plantation				Char. Rehania barren land			
		K	Na	Ca	Mg	K	Na	Ca	Mg
Inland	0-10	0.50	11.5***	3.30***	2.70***	0.30	1.40***	0.30***	0.40***
	10-30	0.40***	10.3**	2.80***	2.85***	0.10***	1.50**	0.40***	0.40***
	30-40	0.40***	9.7***	2.20***	2.40***	0.10***	0.80***	0.30***	0.20***
Middle	0-10	0.40***	12.10***	2.50***	3.00***	0.10***	1.40***	0.40***	0.50***
	10-30	0.40***	11.30***	3.10	3.20***	0.60***	1.40***	0.40	0.50***
	30-40	0.40***	8.6***	2.40***	3.00***	0.10***	0.80***	0.30***	0.40***
Sea side	0-10	0.30	13.1***	2.50***	3.70***	0.20	1.90***	0.40***	0.50***
	10-30	0.30***	11.5***	2.70***	3.70***	0.00***	1.70***	0.30***	0.50***
	30-40	0.30***	11.0***	2.30***	2.70***	0.00***	1.20***	0.30***	0.50***
Land position	Soil depth (cm)	Soil base cations (mmol·kg^{-1})							
		Char Piya plantation				Char Nurul Islam barren land			
		K	Na	Ca	Mg	K	Na	Ca	Mg
Inland	0-10	0.50	12.4**	3.60***	5.30***	0.30	10.6***	2.80***	5.40***
	10-30	0.50***	10.4**	3.70***	4.50***	0.50***	13.8**	2.20***	4.90***
	30-40	0.50***	8.80***	3.40***	3.20***	0.40***	10.7***	2.00***	4.30***
Middle	0-10	0.50***	14.0***	3.20***	4.90***	0.40***	13.2***	2.50***	5.30***
	10-30	0.40***	13.0***	3.80	4.90***	0.30***	11.6***	2.50	3.80***
	30-40	0.40***	12.8***	3.70***	4.30***	0.40***	12.2***	2.30***	4.80***
Sea side	0-10	0.50	15.4***	3.10***	5.40***	0.40	11.3***	2.30***	5.10***
	10-30	0.30***	14.8***	3.10***	5.00***	0.40***	11.7***	2.20***	5.20***
	30-40	0.50***	13.3***	2.90***	4.70***	0.40***	12.1***	2.20***	3.20***

Notes: *** indicate significance difference at p≤0.001for the means between two land uses at each soil depth.

Available K contents in the Char Alim plantation at inland, middle part and sea side in surface soil were 0.50, 0.40 and 0.30 mmol·kg^{-1}, respectively, while their corresponding values 0.30, 0.10 and 0.20 mmol·kg^{-1} in Char Rehania barren land. Available K content at the same soil depth at Char Piya coastal plantation was the same (0.50 mmol·kg^{-1}) at all the three land positions and their corresponding values in Char Nurul Islam barren land were 0.30, 0.40 and 0.40 mmol·kg^{-1} (Table 4). Vadivelu et al. (1993) found that available K gradually declined with depth, which was in support of the present study. Differences between each of the plantations and each of the adjacent barren lands at three different depths for other three base cations at Hatiya (Table 4) were also in agreement with findings reported by Hossain (2002) and Gill and Abrol (1990).

Conclusion

The obvious effects of coastal plantation at Hatiya coast of Bangladesh are: more deposition of finer particles; increase in soil physicochemical properties such as moisture content, organic matter and C, total N and available Ca; and decrease in soil pH up to 40-cm soil depth at inland, middle part and sea side. Available P, K and Mg contents did not show any definite trend between coastal plantations and adjacent barren lands. However, their contents have a tendency to increase in plantation. These findings justify the goal of coastal afforestation for stabilizing newly accreted land with ultimate transfer to people due to heavy demand for agriculture in this over populated country. In the past

many stabilized land through coastal afforestation was also transferred to people for agriculture in this long coastal region. Newly accreted lands along the coasts of Bangladesh, therefore, need to be brought under plantation for stabilizing the fragile coastal sediments and to reduce destructions from natural calamities such as cyclone and tornado occurring frequently in the country.

References

Ball DF. 1964. Loss on ignition as an estimate organic matter and organic carbon in non-calcereous soil. *Journal of Soil Science*, **15**: 84−92.

Bandyopadhyay AK. 1995. *Coastal soil and their management*. Dehradun: International book distributors, Rajpur Road, Dehradun, India, 135pp.

Boto KG, Wellington JT. 1984. Soil Characteristics and Nutrient Status in a Northern Australian Mangrove Forest. *Estuaries*, **7**(1): 61−69.

Cardona P, Boetro L. 1998. Soil characteristics and vegetation structure in a heavily deteriorated mangrove forest in the Caribbean coast of Colombia. *Biotropica*, **30**(1): 24−34.

Das S, Siddiqi NA. 1985. *The mangrove and mangrove forests of Bangladesh.* Mangrove Silvicultural Division. Bulletin No.2.UNDP/FAO/Project BGD/79/017, Bangladesh Forest Research Institute, 142pp.

Eswaran HE, van der Berg, Reich P. 1993. Organic carbon in soils of the world. *Soil Science Society American Journal*, **57**: 192−194.

Gill HS, Abrol IP. 1990. Evaluation of coastal sandy soils and their saline ground waters for afforestation: A case study from India. *New Forest*, **4**: 37−53.

Gunasekaran S, Jayapaul A, Raju PM. 1992. Distribution of mangrove plants in relation to the chemical characteristics of the soil. Muthupet, Tamil. *Asian Environment*, **14**(3): 59−69.

Haque SMS, Hossain M.K, Kabir MA. 2000. Performance of some common mangrove species in Sitakunda and Mirersarai Forest Ranges under Chittagong Coastal Afforestation Division, *The Chittagong. Univ. J. Sci.*, **24**(2): 1−10.

Hasan MM. 2000. Soils and problem soils of Bangladesh. Observer Magazine, Dhaka. 5th May, 23−24pp.

Hossain MM. 2002. Soil nutrients and plant growth in sea side and estuarine mangrove plantations at Coxs Bazar. Institute of Forestry and Environmental Sciences, University of Chittagong, **30**: 125 pp.

Huq FMI, Didar-Ul-Alam M. 2005. *A Handbook on Analyses of Soil, Plant and Water*. Dhaka: Bangladesh-Australia Center for Environmental Research (BACER-DU), 246pp.

Integrated Coastal Zone Management Project (ICZMP), 2007. http://www.iczmpbangladesh.org/. Page last modified: 19 March 2006 and downloaded at 10.30am, 23 August 2007.

Johnston D, Alongi DM. 1995. Comparative study of soil properties in Mekong delta and Cao Mao Hill forest, Vietnam. *Canopy International*, **25**(2): 6−7.

Kabir FMA. 2005. *Coastal afforestation effects on soils at Kattali, Chittagong*. Chittagong: Institute of Forestry and Environmental Sciences, University of Chittagong, 72 pp.

Khan ZH, Husain MS, Mazumder AR. 1998. Properties of soils from the offshore Islands of Bangladesh. *Bangladesh Journal of Forest Science*, **27**(2): 114−120.

Lacerda LD, Ittekkot V, Patchineelam SR. 1995. Biogeochemistry of mangrove soil organic matter: a comparison between *Rhizophora* and *Avicennia* soils in south-eastern Brazil. *Estuar Coast Shelf Sci*, **40**: 713−720.

Machiwa JF, Olfasson E. 1998. Distribution and remineralization of organic carbon in sediments of a mangrove stand partly contaminated with sewage waste. *Ambio*, **27**(8): 740−744.

Matthijs S, Tack J, Speybroeck van D, Koedam N. 1999. Mangrove species zonation and soil redox state, sulphide concentration and salinity in Gazi Bay (Kenya), a preliminary study. *Mangrove & Salt Marshes*, **3**(4): 234−249.

Pal D, Dash AK, Gupta SK, Sahoo AK. 1996. Vegetation pattern and soil characteristics of some mangrove forest zones of the Sundarban, West Bengal. *Indian Agriculturist*, **40**(2): 71−78.

Petersen L. 2002. *Analytical methods of soil, water, plant material and fertilizer. Soil resources management and analytical services*. Comilla, Bangladesh: Soil Resource Development Institute, 17−19 pp.

Rao PVS, Raju S. 2007. Ecological Importance of Mangrove Trees–the example of *Bruguiera gymnorrhiza* (L.) Lamk. (*Rhizophoraceae*). Available at http://www.envfor.nic.in/news/ap

Shaifullah KM, Mezbahuddin M, Sujauddin M, Haque SMS. 2008. Effects of coastal afforestation on some soil properties in Lakshmipur coast of Bangladesh. *Journal of Forestry Research*, **19**(1): 32−36.

Shamsuddin AKM, Mehdi SA. 2003. Concept note on expectations, experiences and priorities for afforestation and reforestation under the Clean Development Mechanism (CDM). Bangladesh Report. Regional Workshop on Forests and Climate Change: Preparing for Decisions on Land Use & Forestry at COP9, Manila, Philippines 16−17 October.

Siddiqi NA. 2001. *Mangrove Forestry in Bangladesh*. Bangladesh: Institute of Forestry & Environmental Sciences, University of Chittagong, Chittagong, Bangladesh, 201pp.

Singh NT, Mongia AD, Ganeshamurthy AN. 1985. Soils of Andaman and Nicobar Islands. *CARI* Bull., No.1, 77 pp.

Sukardjo S. 1978. *Characteristics of mangrove soils of Java. Rimba Indonesia.* Paper presented at the Symposium on Human Uses of Mangrove Environment and Management Implications, Dacca, Bangladesh, 4-10 December, **16**:141−150.

Tam NFY, Wong YS. 1998. Variations of soil nutrient and organic matter content in a subtropical mangrove ecosystem. *Water*, *Air*, *and Soil Pollution*, **103**: 245−261.

Vadivelu S, Muralidharan A, Bandyopadhyay AK. 1993. Soils of Lakshadweep Islands. *CARI*, Bull. No.9, 83 pp.

Watt MS, Coker G, Clinton PW, Davis MR, Parfitt R, Simcock R, Garrett L, Payn T, Richardson B, Dunningham A. 2005. Defining sustainability of plantation forests through identification of the site quality indicators influencing productivity-A national view for New Zealand. *Forest Ecology and Management*, **216**: 51−63.